CHAPTER 2

SWITCHGEAR ASSEMBLIES 600V OR LESS

2-1. Periodic Maintenance.

A periodic maintenance schedule must be established to obtain the best service from the switchgear. Annual check should be made on all major switchgear devices after installation. After trends have been established regarding the equipment condition and reliability, the maintenance interval may be extended (18–36 months) in keeping with the operating conditions. A permanent record of all maintenance work should be kept. The record should include a list of periodic checks and tests made (including date of test), condition of the equipment, repairs or adjustments performed, and test data that would facilitate performing a trend analysis. Maintenance personnel must follow all recognized safety practices, both the nationally published standards and military regulations. Some specific suggestions in dealing with switchgear maintenance are given below:

a. Tools designed for slowly closing switchgear circuit breakers or other devices during maintenance are not suitable for use on an energized system. The speed necessary for device closing is as important as its speed in opening; therefore, a wrench or other manual tool is not fast enough.

b. Before working on a switchgear enclosure, verify that the enclosure is de-energized by checking for voltage using a voltage detector.

c. Disconnect all drawout or tilt-out devices such as circuit breakers, instrumentation transformers, and control power transformers.

d. Do not lay tools on the equipment while working. It is all too common to forget a wrench when closing up an enclosure. Don't take the chance.

e. Never rely upon the insulation surrounding an energized conductor to provide protection to personnel. Use suitable safety clothing and equipment.

f. Always use the correct maintenance forms and equipment. When performing maintenance the following should be available:

(1) Forms for recording the conditions as found and work done.

(2) Control power connections, test couplers, and spare parts recommended by the manufacturer to facilitate repair and maintenance of each type of circuit breaker.

(3) Special tools, such as lifting mechanisms for removing and transporting power circuit breakers, relay test plugs for testing and calibrating protective relays, a low resistance ohmmeter for measuring the resistance of contacts, ammeters, voltmeters, megohmmeters, low voltage/high current test sets for testing power circuit breakers, and other special test equipment.

(4) Manufacturer's instruction books regarding the maintenance of switchgear devices such as circuit breakers, relays, bus bars, meters, etc. The fundamentals that are presented in the upcoming sections are designed to supplement these instructions, giving the elements of the overall maintenance program rather than the details.

2-2. Metal enclosures.

Maintenance is recommended below:

a. With power off and the bus properly grounded, open the enclosure and remove any accumulated dust and dirt. Vacuum cleaning is recommended; blowing with compressed air is not.

b. Check structure and anchor bolts for tightness. For bus and breaker connections ensure manufacturer's specified torques are used.

c. Clean and lubricate circuit breaker racking mechanisms with a non-hardening, non-conductive grease.

d. Inspect operation and adjustment of safety shutters, mechanical and key interlocks, auxiliary and limit switches.

e. Clean and inspect strip heaters.

f. Clean any air filters that are installed in the ventilation openings.

g. Inspect all relays, contractors, switches, fuses, and other auxiliary devices for correct operation and cleanliness.

h. Tighten control wiring connections.

i. Inspect alignment and contacting of primary disconnecting devices, checking for signs of abnormal wear or other damage. Discoloration of these or other silvered surfaces is not usually harmful unless caused by sulphide deposits, which can be removed by a solvent, such as alcohol, or silver polish.

j. After cleaning, measure the resistance to ground and between phases of the bus with a megohmmeter (para 14-2). It is not possible to give definite limits for satisfactory insulation resistance values, so that a change in the reading from one inspection period to another is the best indication of any weakening tendency. The readings should be taken under similar conditions each time, and the record should include temperature and humidity.

k. Before replacing the breaker, wipe the primary disconnecting device contacts. Apply a thin coat of contact lubricant to the stationary studs and to the primary disconnects on the breaker.

l. Ensure that all metal shields are securely in place. These shields must be installed to confine any blast in the event of circuit breaker failure.

(1) *A note on lubricants.* One of the most useful lubricants for motors is an extreme pressure (EP) lithium-base petroleum grease. As the usage of Class F winding temperature ratings has increased, however, others have adopted synthetic greases to withstand higher bearing temperatures.

(2) *Synthetic oils and greases.* Synthetic oils and greases compounded from various silicones, alkyl benzene, diesters, and fluorinated ethers, are available for extremely high-temperature service that would cause premature oxidation of petroleum lubricants. Some synthetics also suit extremely low temperature, down to 40 or 50 degrees below zero. The main uses for synthetic lubricants in motor bearings are reduced friction and resistance to moisture and chemical contamination. Such applications must be carefully worked out with bearing and lubricant suppliers, because no universal lubricant formulation will apply to all environments. However, it is not unusual for lubricant to vary little more than brand name. Thus substitutions are often possible. Consult with the manufacturer of the switchgear to determine the important characteristics of the lubricant prior to specifying a substitute lubricant. Carefully selected substitutes will reduce the cost of procurement, stocking and dispensing.

2-3. Bus bar and terminal connections.

Many failures are attributable to improper terminations, poor workmanship, and different characteristics of dissimilar metals. Loose bus bar or terminal connections will cause overheating which can be easily spotted by a discoloration of the bus bar. A thermographic survey can be conducted to detect overheating before discoloration occurs (para 14-7). An overheating condition will lead to deterioration of the bus system as well as to equipment connected to the bus; i.e. protective devices, bus stabs, etc. Therefore, bus bar and terminal connections should be regularly checked to ensure that they are properly tightened without damaging the conductors. Special attention should be given where excessive vibration may cause loosening of bolted bus and terminal connections. Tightening torque values for electrical connections are provided in table 2–1. This information should be used for guidance only where no tightening information on the specific connector is available. It should not be used to replace manufacturer's instructions which should always be followed. Do not assume that once a connection has been torqued to its proper value that it remains tight indefinitely. If signs of arcing are evident, then the connections should be broken and the connecting surfaces cleaned. Because of the different characteristics of copper and aluminum, they should not be intermixed in a terminal or splicing connector where physical contact occurs between them, unless the device is suitable for the purpose and conditions of use. Materials such as solder and compounds shall be suitable for the use and shall be of a type which will not adversely affect the conductors.

a. Aluminum connectors. Special considerations must be given to aluminum connections. Aluminum connectors are plated and should not be cleaned with abrasive. If these connectors are damaged, they should be replaced. It should be noted that when making connections with aluminum conductors, be sure to use a joint compound made for the purpose. To assist in the proper and safe use of solid aluminum wire in making connections to wiring devices, refer to the National Electrical Code. Make aluminum connections with solderless circumferential compression-type, aluminum-bodied connectors UL listed for AL/CU. Remove surface oxides from aluminum conductors by wire brushing and immediately apply oxide-inhibiting joint compound and insert in connector. After joint is made, wipe away excess joint compound and insulate splice.

b. Bus insulators and barriers. Bus bar support insulators and/or barriers should be wiped with a clean cloth. Do not use steel wool or oxide papers to remove dirt; use a cleaning solvent that will not leave trace deposits. While cleaning, check insulators for cracks and signs of arc tracking. Defective units should be replaced. Loose mounting hardware should be tightened.

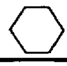
2-4. Underfloor ducts.

All undefloor duct systems require checks for evidence of oil and water. Entrances and fittings should be checked and corrected as necessary to prevent entrance of liquids, insects, and rodents. Cockroaches, ants, beetles and rodents have been known to attack cable insulation, especially if greases or oils are present. External heat and heat caused by overloaded circuits can cause cracking of cable insulation and drying of taped splices. Moisture can then penetrate the cable and could cause a fault. Therefore, underfloor conduits and duct systems should be kept sufficiently clear of electrical and hot water floor-heating systems to prevent undue heating of the enclosures.

2-5. Busways.

Feeder busway, trolley busway and plug-in busway (fig 2–1) require annual cleaning and removal of oil substances and dirt. Ventilated-type busway should

Table 2-1. U.S. standard bolt torques for bus connections heat treated steel.

GRADE	SAE	SAE	SAE	SAE
	1 & 2	5	6	8
TYPICAL MARKING:				
MINIMUM TENSILE (P.S.I.)	64K	105K	133K	150K
BOLT DIAMETER	TORQUE (FOOT POUNDS)			
1/4	5	7	10	10.5
5/16	9	14	19	22
3/8	15	25	34	37
7/16	24	40	55	60
1/2	37	60	85	92
9/16	53	88	120	132
5/8	74	120	167	180
3/4	120	200	280	296
7/8	190	302	440	473
1.	282	466	660	714

NOTE : REDUCE TORQUE BY 20% WHEN CADMIUM PLATED BOLTS ARE USED.

have the bus bars cleaned annually with clean, dry compressed air at a maximum pressure of 50 pounds per square inch. Plug-in devices should be serviced using the same procedures as other switches or breakers. The plug-in bus or prongs should be checked annually for annealing or corrosion on all connections which are rated in excess to 75 percent of the rating of the bus duct. Connections should not be retorqued as part of a routine maintenance procedure unless visibly loose or shown to be loose by an infrared scan. All busway connections should be torqued according to manufactures recommendations. If this information is not available, use the torque specifications in table 2-1. Inspect to ensure that:

a. Ventilation continues to be adequate.

b. Clearances are maintained and encroachment from other equipment facilities has not occurred.

2-6. Power circuit breakers.

Power circuit breakers encompass all breakers except molded case breakers and breakers used for control applications. It is recommended that power circuit breakers be inspected once a year after installation. More frequent inspections are recommended where severe load conditions, dust, moisture or other unfavorable conditions exist, or if the vital nature of the load warrants it. Any breaker that has interrupted a fault at or near its short circuit rating should be inspected immediately after the interruption and serviced if necessary. Reenergize equipment completely before working on any devices, connections, bus work, breaker or feeder cable compartments. This includes deenergizing any connections to outside primary or secondary sources such as transformers, tie lines, etc. Manufacturer's instruction documents should also be obtained and read carefully before disassembly or adjustments are performed.

a. Drawout circuit breakers. A drawout-type breaker should be tested and inspected for proper operation as follows:

(1) Withdraw the breaker to the "test" position. This position disconnects the primary power circuit

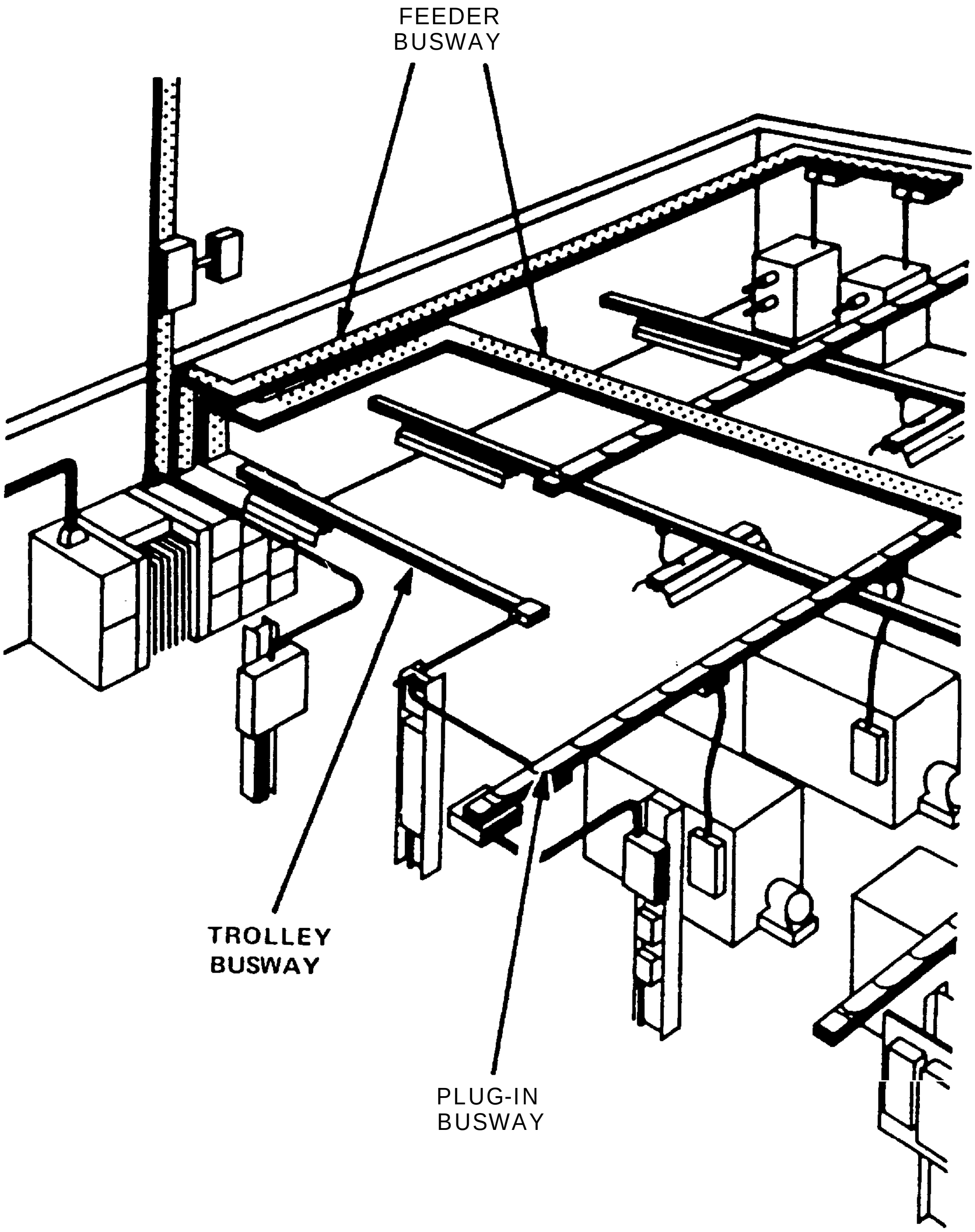


Figure 2-1. Typical busway installation.

but leaves the control circuits energized (fig 2-2). If a "test" position is not provided, then completely withdraw the circuit breaker from its compartment and use a test coupler to provide control power.

(2) Test for voltage to make sure that all paths of potential backfeed from control power circuits, as well as outside sources, are disconnected. This is especially important if an external source of control power is being used for testing.

(3) Operate the breaker and check all functions. Use both the electrical means (when provided) and the mechanical means to charge, close and trip the breaker. This is particularly important for breakers that normally remain in either the opened or closed position for long periods of time.

(4) Remove the breaker from its compartment to a clean maintenance area. Close the compartment door and cover the breaker cutout to prevent access to live parts.

(5) Check and lubricate all safety rollers and auxiliary contacts. Check all mechanical clearances to ensure they are within manufacturer specified tolerances. Also inspect and lubricate bus stabs and

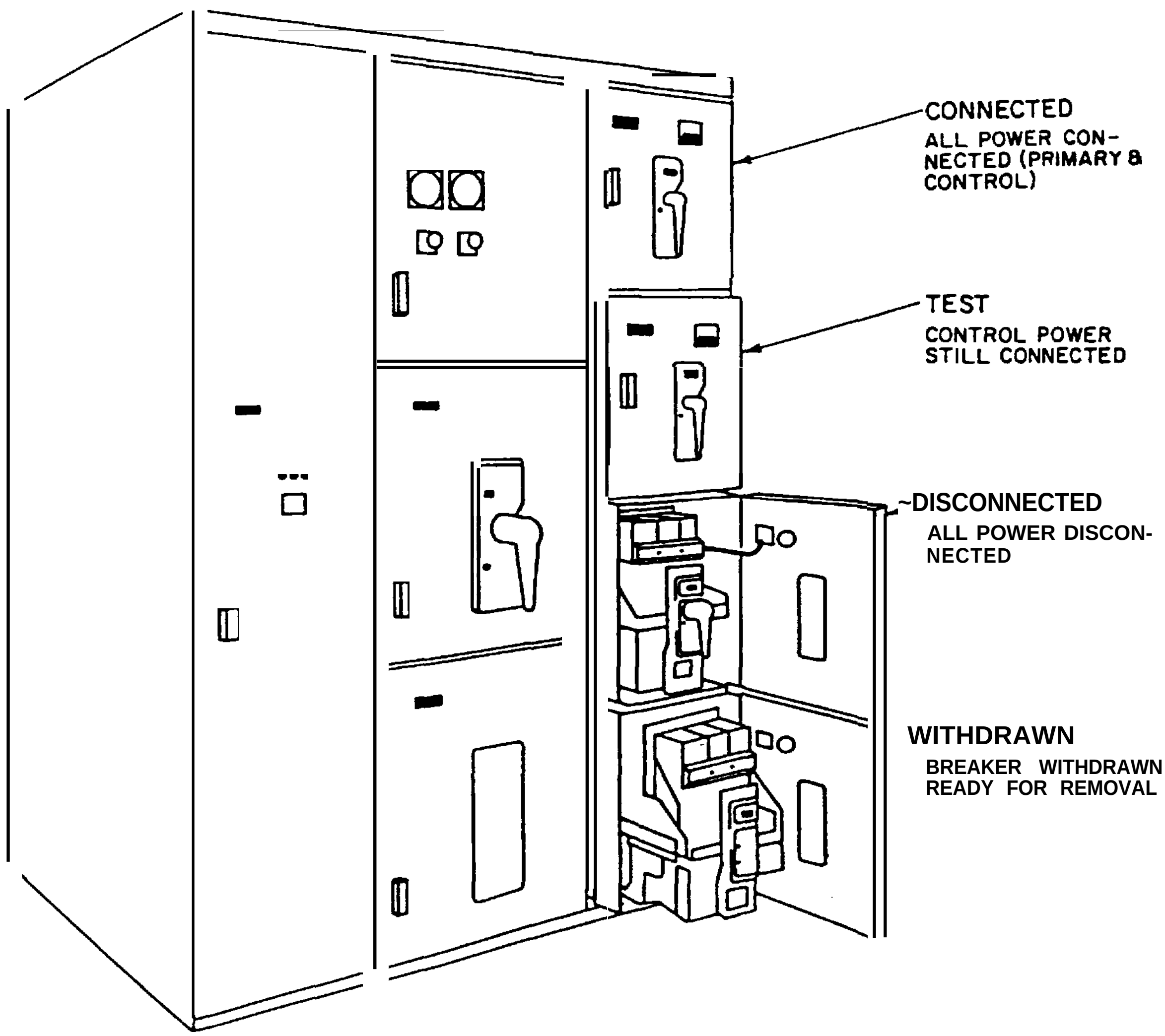


Figure 2-2. Drawout circuit breaker positions.

ac/dc control block contacts. Verify correct operation of "trip free" and anti-pump mechanisms.

b. Fixed circuit breakers. Maintenance on fixed- or bolter-type circuit breakers is normally performed with the breaker in place inside its cubicle. Special precautions must be exercised to assure equipment is de-energized and the circuit in which it is connected is properly secured from a safety standpoint. All control circuits should be de-energized. Stored energy closing mechanisms should be discharged.

c. Power circuit breaker components. Maintenance on all power circuit breakers will encompass maintenance on the following components.

(1) *Insulation.* The general rule for insulation is keep it clean and dry. Remove interphase barriers and clean them and all other insulating surfaces with dry compressed air and a vacuum cleaner. Wipe insulation with clean lint-free rags and solvents as recommended by the manufacturer if hardened or encrusted contamination must be removed. Repair moderate damage to bushing insulation by sanding smooth and refinishing with a clear insulating varnish. Check insulating parts for evidence of overheating and for cracks that indicate excessive thermal aging.

(2) *Contacts. The* major function of the power circuit breaker depends among other things upon correct operation of its contacts. These circuit breakers normally have at least two distinct sets of contacts on each pole, main and arcing (fig 2-3). Some have an intermediate pair of contacts which open after the main contacts and before the arcing contacts.

(a) Main contacts. When the breaker is closed, practically the entire load current passes through the main contacts. Also, short circuit current must pass through them during opening or closing faulted lines. If the resistance on these contacts becomes high, they will overheat. Increased contact resistance can be caused by pitted contact surfaces, foreign material embedded on contact sur-

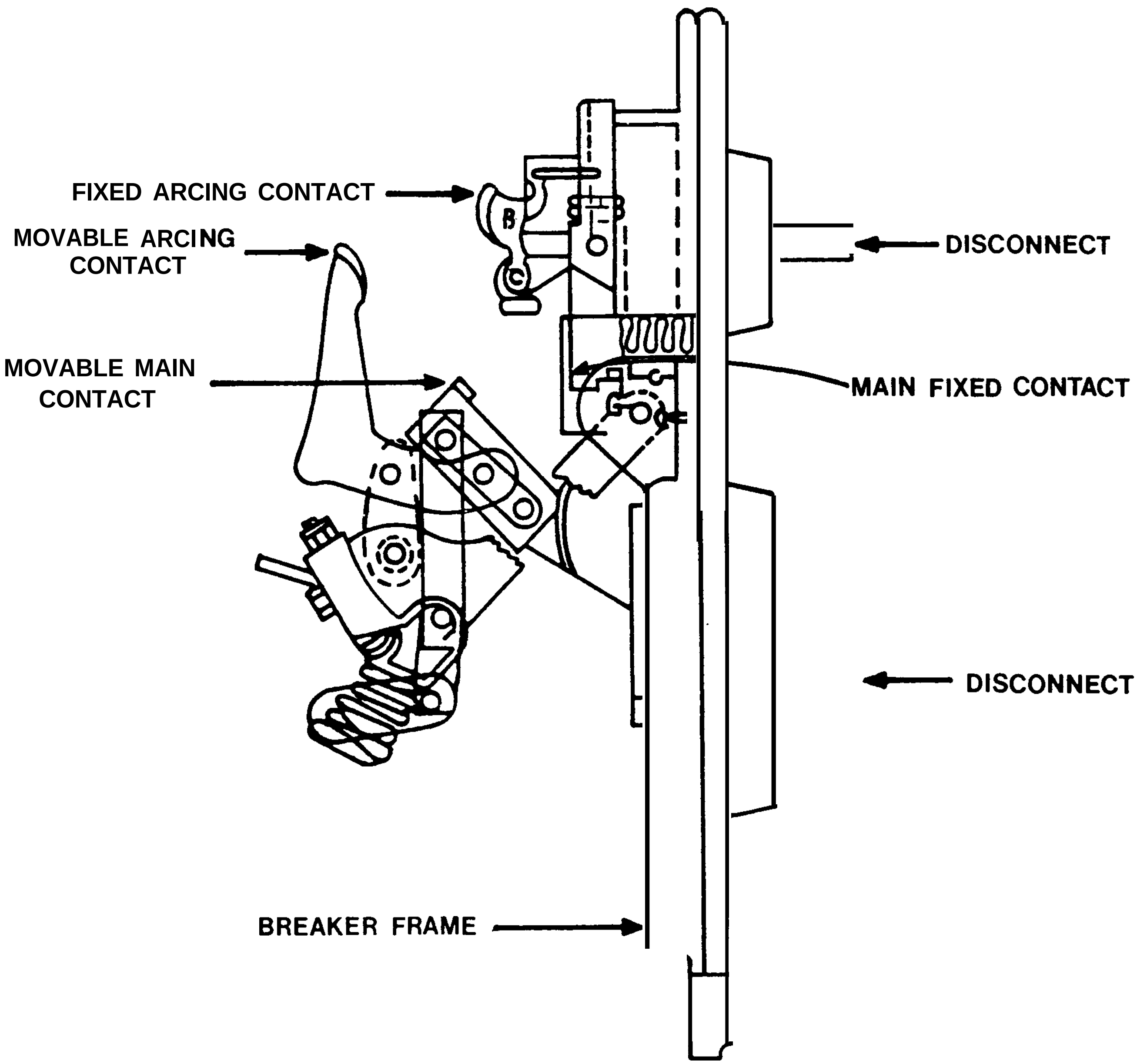


Figure 2-3. Power circuit breaker main and arcing contacts.

faces, or weakened contact spring pressure. This will cause excessive current to be diverted through the arcing contacts, with consequent overheating and burning.

(b) Arcing contacts. Arcing contacts are the last to open; any arcing normally originates on them. In circuit interruption, they carry current only momentarily, but that current may be equal to the interrupting rating of the breaker. In closing against a short circuit, they may momentarily carry considerably more than the short circuit interrupting rating. Therefore, they must make positive contact when they are touching. If not, the main contacts can be badly burned or may result in a failure to interrupt a fault.

(c) Contact maintenance. The general rules for maintaining contacts on all types of breakers are: keep them clean, aligned and well adjusted. To inspect the circuit breaker contacts, the arc chutes must be removed. When doing this, check the arc chutes for evidence of damage, and replace damaged parts. If not damaged, then blow off dust or loose particles. Once the main contacts are exposed, inspect their condition. Slight impressions on the stationary contacts caused by the pressure and wiping action of the movable contacts is tolerable. Contacts which have been roughened in service should not be filed but large projections, caused by unusual arcing, should be removed by filing. When filing, take care to keep the contacts in their original de-

sign. That is, if the contact is a line type, keep the area of contact linear, and if ball type, keep the ball shaped out. Discoloration of silver-plated surfaces is not usually harmful unless caused by insulating deposits. These deposits should be removed with alcohol or a silver cleaner. Whether cleaned or not, lubricate the main contacts by applying a thin film of slow aging, heat resistant grease. All excess lubricant should be removed with a clean cloth to avoid accumulation of dirt and dust. Under no circumstances should the arcing contacts be lubricated. Where serious overheating is indicated by discoloration of metal and surrounding insulation, the contact and spring assemblies should be replaced in accordance with manufacturer's instructions. While carefully closing the circuit breaker, check for proper gap, wipe and contact alignment. Contact gap is the distance between the stationary and movable contacts with the circuit breaker in the fully open position. If the arcing contact gap is too small, a circuit breaker may not be able to interrupt a fault. If the main contact gap is too small, the main contacts will interrupt the fault along with the arcing contacts and possibly burn the main contacts. Contact wipe is the amount of over travel between the stationary and movable contacts from the time when the contacts are just touching to the time when the circuit breaker is fully closed (figs 2–4, 2–5, and 2–6). Check that all contacts make and break at approximately the same time. Make adjustments in accordance with the manufacturer's recommendations. Laminated copper or brush style

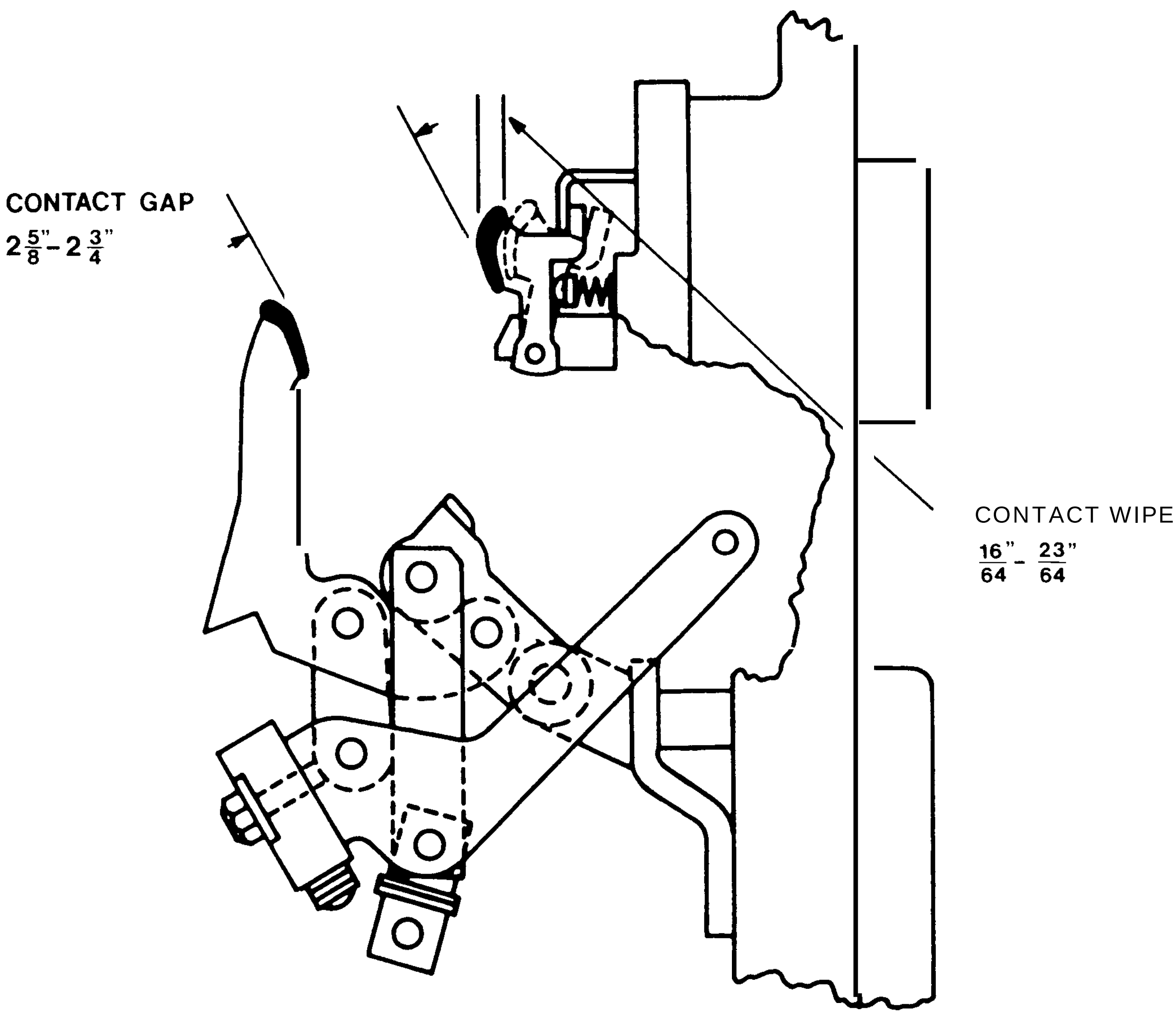


Figure 2-4. Arcing contact gap and wipe.

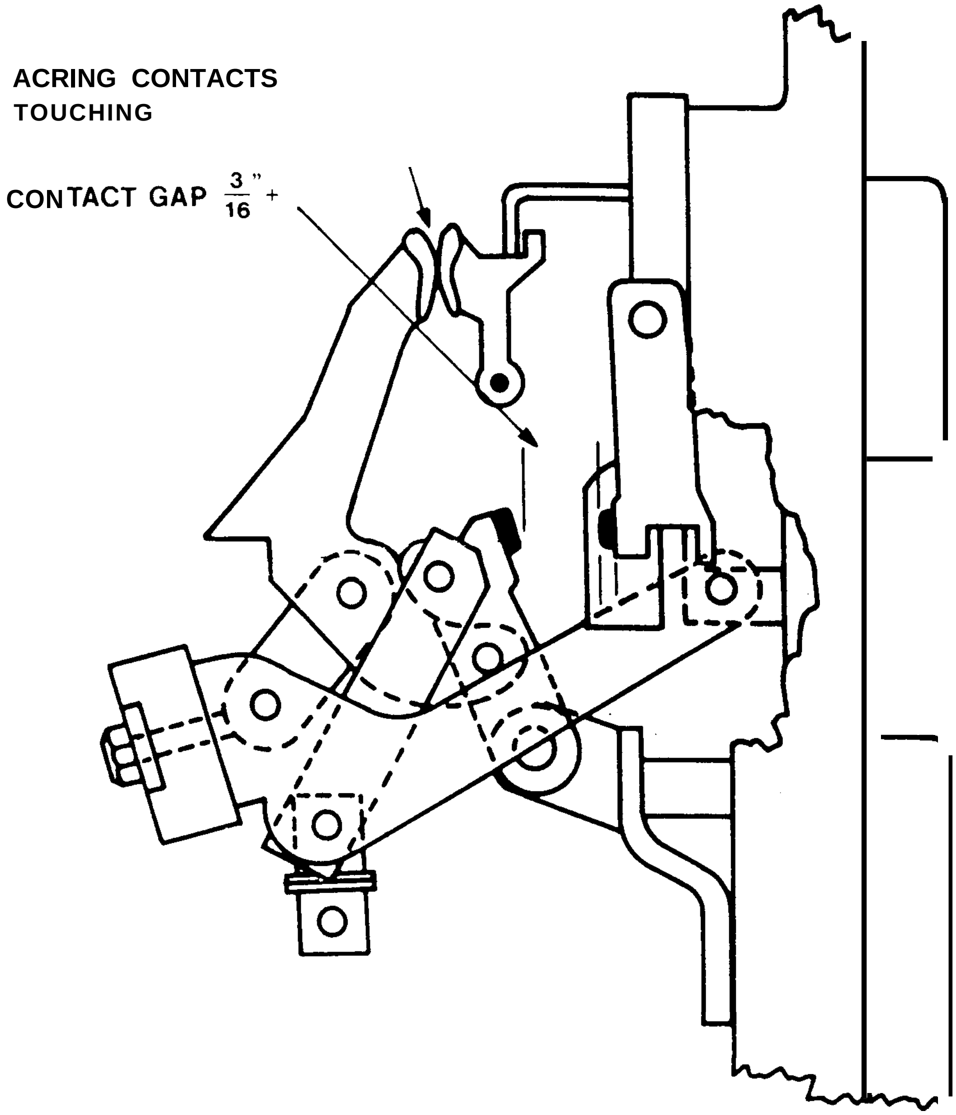


Figure 2-5 Intermediate contact gap.

contacts found on older circuit breakers should be replaced when badly burned. Repairs are not practical because the laminations tend to weld together when burning occurs, and contact pressure and wipe are greatly reduced. These contacts may be filed to remove large projections or to restore their original shape. They should be replaced when they are burned sufficiently to prevent adequate circuit breaker operation or when half of the contact surface is burned away. Carbon contacts, used on older circuit breakers, require very little maintenance. However, inadequate contact pressure caused by erosion or repeated filing may cause overheating or interfere with their function as arcing contacts.

(3) *Operating mechanism*. The purpose of the operating mechanism is to open and close the breaker contacts. This usually is done by linkages connected, for most power breakers, to a power operating device such as a solenoid or closing spring for closing, and contains one or more small solenoids or other types of electro-magnets for tripping. Tripping is accomplished mechanically, independent from the closing device, so that the breaker contacts will open even though the closing device still may be in the closed position. This combination is called a mechanically trip-free mechanism. After closing, the primary function of the operating mechanism is to open the breaker when it is desired, which is whenever the tripping coil is energized at above its rated minimum operating voltage. The breaker operating mechanism should be inspected for loose or broken parts; missing cotter pins or retaining keepers; and missing nuts and bolts. It should also be examined for damage or excessive wear on cam, latch, and roller surfaces. Excessive wear usually results in loss of travel of the breaker contacts. It can affect operation of latches; they may stick or slip off and prematurely trip the breaker. Adjust-

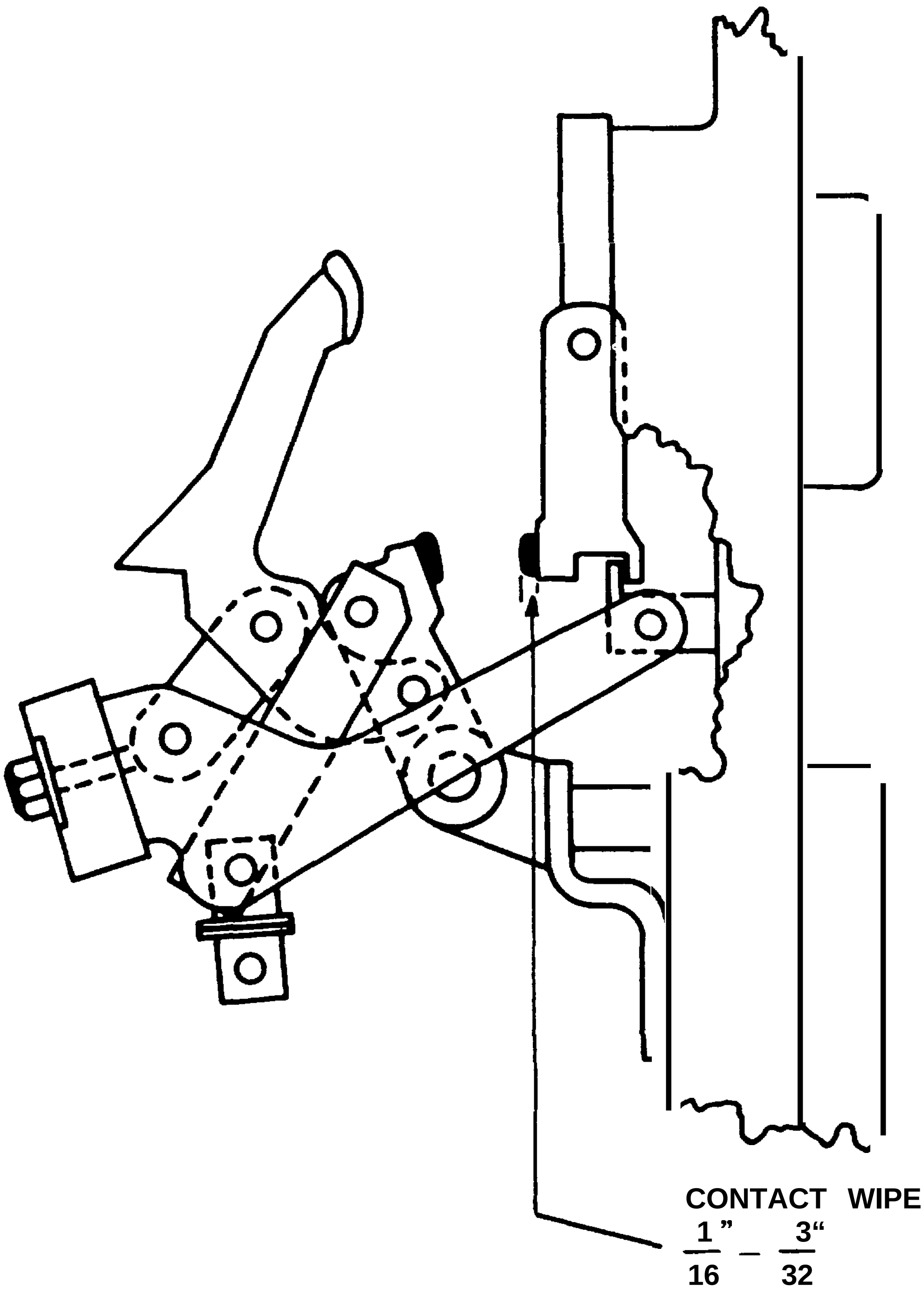


Figure 2-6. Main *contact wipe.*

menta for excessive wear are possible for certain parts. For others, replacement is necessary. The closing and tripping action of a breaker should be quick and positive. While documenting, operate the breaker several times, checking for obstructions or excessive friction. Any binding, slow action, delay in speration, or failure to trip or latch must be conrected prior to returning to service. Clean and relubricate the operating mechanism. Use a nondetergent light machine oil (SAE-20 or 30) to lubricate pins and bearings not disassembled. Use a non-hardening and non-conductive grease to lubncate the ground or polished surfaces of cams, rollovers, latches and props, pins and bearings that are removed for cleaning. Check the breaker operating mechanism adjustments and readjust as described in the manufacture% instruction book. If these adjustments cannot be made within specified tolerances, it will usually indicate excessive wear and the need for a complete overhaul.

(4) *Trip devices.* The trip devices on low voltage circuit breakers provide the electrical decisions needed to detect the difference between normal and abnormal conditions of current flow. The maintenance and adjustment of these devices is just as important as the work performed on the main contacts and operating mechanism. The trip devices are either electro-mechanical or solid-state. Both types are responsible for providing various degrees of fixed, short, or inverse time delays based on the amount of current they sense. The electro-mechanical type, with an air or fluid dashpot for time delay, should be tested as part of the maintenance work performed. A dashpot is a pneumatic or hydraulic device used for cushioning or damping of movement to avoid mechanical shock and consisting essentially of a cylinder containing air or liquid and a piston moving in it. Testing of the electro-mechanical devices requires the use of a low voltage (about 0-20V) but high current (usually O-50,000A) primary injection test set designed specifically for this purpose. Calibration tests should be made to verify that the performance of the device is within the values shown on the manufacturer's published curves; taking into account that the time-current curves are plotted as a band of values rather than a single line (fig 2–7). Pay careful attention to how the manufacturer has presented the curve data. There is a wide variety of formats. Check to see that the current is in amperes or multiples of a pickup value and whether temperature ranges or previous conditions will affect results. Usually, the trip devices are tested one unit at a time. There are some devices which may use a thermal element for time delay. These may have to be tested all at once to get results similar to those published by the manufacturer. Check the test conditions carefully. If the trip devices do not operate properly, the calibration and timing components should be adjusted or replaced per the manufacturer's recommendations. If repair or replacement of the electro-mechanical devices is being considered, then thought should be given toward retrofitting the existing breaker with solid-state trip devices. This newer technology is generally more reliable because the parts used to make the trip unit do not drift out of adjustment or suffer the effects of aging or contamination to the same degree as their electro-mechanical forerunners. If the breakers are already equipped with solid-state trip devices, they should also be checked for proper operation and time delay in accordance with the manufacturer's published curves. The test procedure recommended by the manufacturer should be followed.

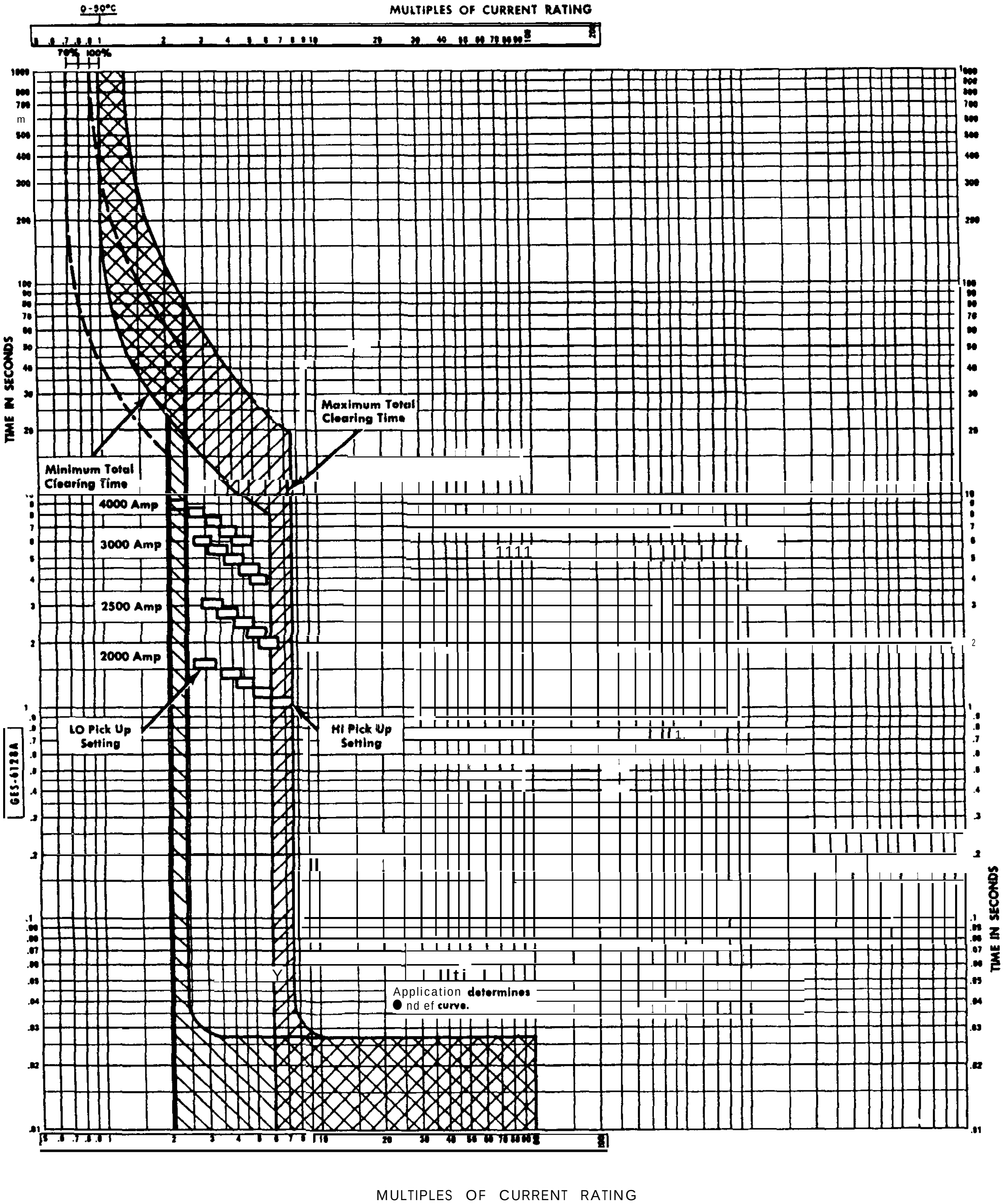
(5) *Auxiliary devices.* Inspect the closing motor or solenoid, shunt trip coil and mechanism, alarm mechanisms, and the control wiring for correct operations, insulation condition and tightness of connections. Check on-off indicators, spring-charge indicators, mechanical and electrical interlocks, key interlocks, and lock-out fixtures for proper operation and lubricate where required. In particular, test the positive interlock feature which prevents the insertion or removal of the breaker while it is in the closed position. Check control devices for freedom of operation. Replace contacts when badly worn or burned. After the breaker has been serviced, manually operate it slowly with a closing device to check for tightness or friction and to see that the contacts move to their fully open and fully closed positions. Electrically operate the breaker several times to check the performance of the electrical accessories using the "TEST" position, an external test/control cabinet, or a test coupler.

2-7. Network protectors.

The current-carrying parts, main contacts, and operating mechanism of a network protector are very similar to those of the air circuit breaker. This similarity usually ends with the principal mechanical devices. Unlike the usual feeder circuit breaker, the network protector is more like a tie circuit breaker; that is, it is almost always energized on both sides. This condition requires that extreme care be taken during installation or removal of the unit from service. The network protector is equipped with special relays that sense the network circuit conditions and command the mechanism to either open or close automatically in response to those conditions. Network protectors are used where large amounts of power must be distributed to high density load areas such as commercial buildings and office complexes. To form a network, several incoming power sources may be connected. As a result, a short circuit at any point in the system usually involves very high fault currents.

a. Safety precautions. Due to the construction and purpose of the network protector, taking it out of service or placing it back in service is a procedure that must be done while the circuit is energized. During this work, always use the special insulated tools provided with the particular model to be serviced. Alternate or make-shift tools are not recommended unless they have been laboratory tested and are known to have good safety performance. Electrical grade, safety gloves should still be worn by the person servicing the unit regardless of the type or condition of the tools used.

b. Maintenance. A routine maintenance schedule for network protectors should be observed. The frequency of inspection will vary based on the location and environment in which the unit is installed, and



GENERAL ELECTRIC	MOLDED-CASE CIRCUIT BREAKER	GES-61 28A
Current Ratings 3000A Frame – 2000. 2500 and 3000 amperes 4000A Breaker — 4000 amperes **Voltage Ratings** 600 volts a-c, 250..41, d . **Frequency Rating** 60 Hertz	**POWER BREAK'"** Type THS (3000A Frame & 4000A Breaker) Long-time Delay and Instantaneous Time-current Curves Curves show circuit breaker t. .,." air, 0-50 C ambient, (wired with co. ductors of corresponding ratin g. . a prior load.)	**Adjustments** Standard long time magnetic delay, 100"/. of rating, not adjustable. Optional THS adjustable trip, 70-100./. of rating Instantaneous magnetic trip, continuous od-i., tment. +., tory sel o. HI Bloc h, show trip range at each setting.

11 73 (5M) GENERAL ELECTRIC CO., CIRCUIT PROTECTIVE DEVICES PRODUCI DEPT., PLAINVILLE, CONN. K!15 ,*, A

Figure 2-7. Electromechanical trip device time-current curve.

the number of operations the unit has made. In all cases, open the circuit first. This is done by moving the control handle from "AUTOMATIC" to "MANUAL" and then manually opening the circuit. The control handle and/or operating mechanism should then be locked in the "OPEN" position before further work is done. Maintenance should include cleaning any accumulation of dust, dirt or corrosion deposits, a thorough visual inspection, and overall performance tests. Should the operation of any part be suspect, refer to the manufacturer's instructions describing operation, adjustment, and replacement of these parts. If the network sensing relays are out of calibration, they should be recalibrated by competent shop personnel. The network protector is housed in a cell or enclosure similar to those used for air circuit breakers (fig 2-8). The circuit breaker mechanism and the network relay panel assembly of a network protector are usually constructed aa an integral, drawout unit which must be withdrawn fmm the housing for proper maintenance. Removal is done by unbolting the fuses at the top (usually) and the disconnecting links at the bottom (some models have bolt-actuated disconnecting fingers at the bottom). After removing any additional lock-down bolts or latches, the drawout unit may be carefully withdrawn using the rails provided for support. Although this provides a comparative measure of safety, work should be done cautiously since there is voltage present within the enclosure. It is better to move the unit completely away from the enclosure (fig 2–9). The following inspection and maintenance operations can be done on the drawout unit:

(1) Clean the breaker assembly. Use of a vacuum cleaner is preferred. Use cloth rags free of oil or grease for removing clinging dirt.

(2) Remove arc quenchers. Replace if damaged.

(3) Inspect main contacts (fig 2-10). Smooth any heavily frosted area with a very fine file or a burnishing stone which does not shed abrasive particles. Protect hinged joints from falling particles during filing.

(4) File smooth any especially high projections of metal on arcing contacts.

(5) See that all electrical connections are tight.

(6) Look for any abrasion of wire insulation and repair.

(7) Check for signs of overheating of control wire and current carrying parts.

(8) See that all springs are in good condition and are properly seated in place.

(9) See that all nuts, pins, snap rings or retainers, and screws are in place and tight.

(10) Replace any broken or missing barriers.

(11) With the rollout unit still set aside, perform the following maintenance operations inside the enclosure:

****WARNING****

Both source and load terminals are probably still energized. Use insulated tools and safety protective equipment for this work. Do not remove any barriers from the enclosure.

(a) Look for loose hardware on the enclosure bottom or beneath the frame. If any is found, trace to source and correct problem or replace.

(b) Clean stand-off bus insulators.

(c) Remove oxide film from terminal contacts if necessary.

(12) Manually close and trip the breaker mechanism according to instructions furnished for the particular model.

(13) Perform an operational test using a network protector test kit.

(14) Conduct insulation resistance tests, dielectric test and electrical operating test in accordance with the manufacturer's recommendations.

(15) Carefully replace the drawout unit in the enclosure. Make a final inspection to be sure no control wiring has become snagged, and that no plugs or connecting surfaces have been bent or damaged.

2-8. Auxiliary switchgear equipment.

Auxiliary equipment includes devices such as fuses, capacitors, meters, relays, etc. This equipment should be serviced along with the major switchgear components, unless there is some indication that a device is being heavily or improperly used, in which case it should be inspected more often. Protective relays and meters should be inspected and calibrated on a scheduled basis. Critical service equipment should have the protective relays checked at every maintenance turn (annually or according to manufacturer's recommendations). Relays applied to other general distribution circuits may be done less frequently (see para *2-8h).*

a. Fuses. Fuse maintenance is covered as a separate category of electrical equipment (para *5-4d).*

b. Capacitors. The maintenance requirement on power capacitor installations is so small that its

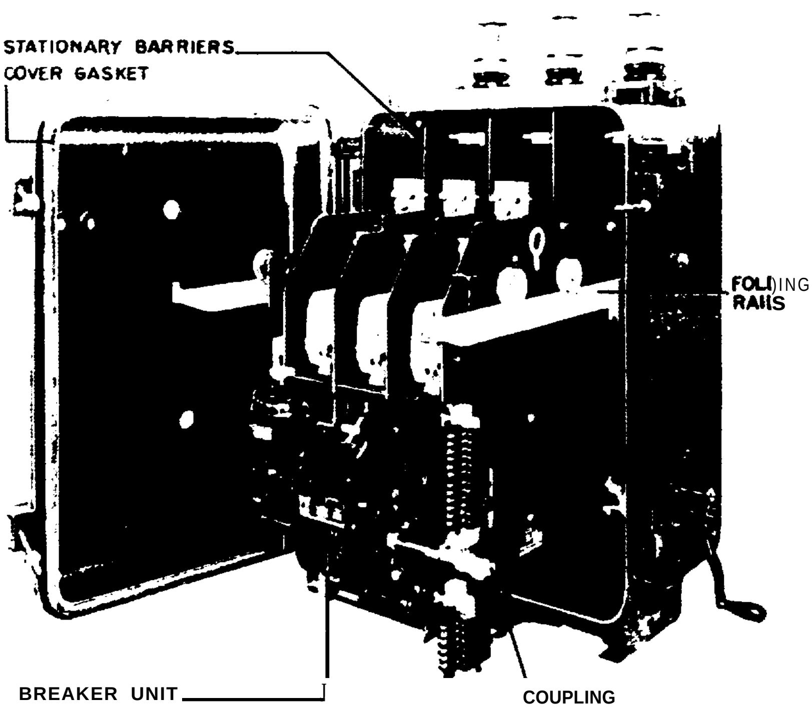


Figure 2-8. Typical drawout network protector and enclosure.

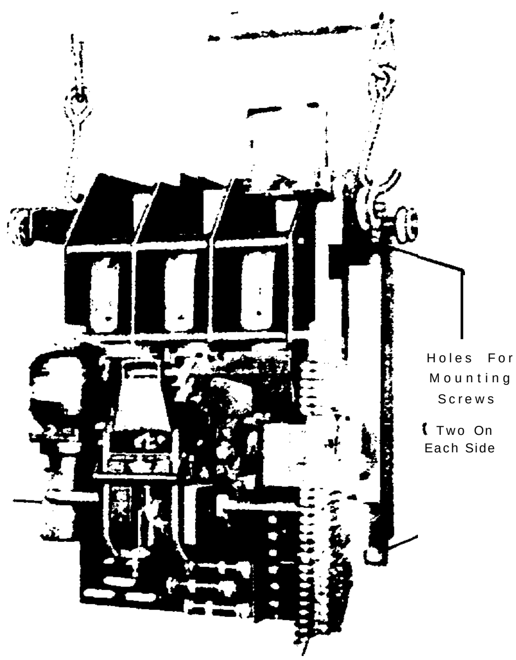


Figure 2–9. Network protector removable unit.

importance is often overlooked. The voltage of the system at the capacitor location should be checked at light load periods to determine if an overvoltage condition exists. Any changes in circuit connections, which may increase voltage levels, warrant a re-check of operating conditions. The conductor sizes should provide for not less than 135 percent of capacitor current at rated voltage and WA. As a general rule, if the side of the capacitor unit casing is operating at a temperature above 55 degrees C (131 degrees F a temperature almost too hot for bare-hand contact), then a more complete investigation of operating conditions should be made. The case temperatures should never exceed 65 degrees C (149 degrees F) under any conditions. Adequate ventilation is therefore necessary to remove the heat generated by continuous full-load duty. Remove any obstructions at ventilation openings in capacitor housings to ensure that this ventilation is maintained. A disconnected capacitor retains its electrical charge for some time and may even retain the full-line voltage across its terminals. Therefore always discharge a capacitor before handling or making connections. An insulation short circuit jumper may be used for this purpose; however, it should only be applied with full knowledge of the circuit, and with the use of appropriate protective equipment. Power capacitors are generally provided with individual fuses to protect the system in case of a short circuit within the capacitor. In addition to a faulty capacitor, a fuse may be blown by an abnormal voltage surge. Check for blown fuses and replace them with a type recommended by the manufacturer. Do not remove fuses by hand until the capacitor has been completely discharged. Clean the case of a capacitor, the insulating bushings, and any

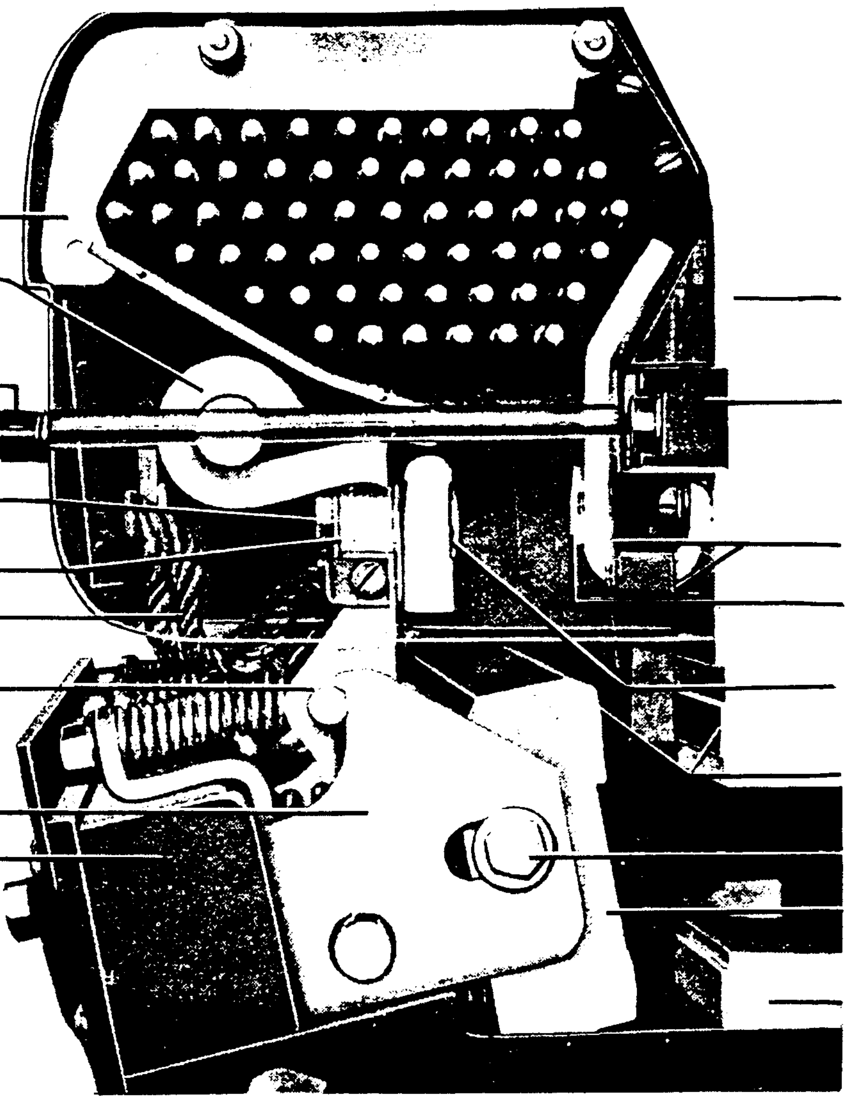


Figure 2–10. Typical contact construction for a network protector.

connections that are dirty or corroded. Inspect the case of each capacitor for leaks, bulges, or discoloration. If any of these conditions exist, then replace the capacitor (para 11–2).

c. Battery supplies. The control battery is such an important item in switchgear operation that it must be given strict attention in the maintenance program. The battery charger plays a critical role since it supplies normal direct current (DC) power to the station and maintains the batteries at a high level of charge. The batteries, in addition to supplying temporary heavy demands in excess of the charger capacity, serve as a back-up source to trip breakers upon loss of alternating current (AC) power. Failure of the charger or its AC supply transfers all DC load to the batteries. Each battery cell electrolyte level should be checked. While a single cell may not produce a serious shock hazard, when the cells are connected in a battery bank, a severe shock hazard may be possible. Also, there are usually many exposed connections, and safety gear and tools must be used to the best degree of safety such as face shields, acid/caustic resistant gloves, emergency eyewash, etc. Electrolyte is the fluid contained in each battery cell (fig 2–11). Low electrolyte levels indicate too high a charging rate. In this case, the "float-voltage" setting of the charger should be checked against the battery manufacturer's recommendations. The specific gravity of the battery electrolyte should be taken using a hydrometer (para 14-6). If the readings between battery cells vary more than fifty points on the hydrometer scale, the battery probably has a bad cell which should be replaced. If all cells read consistently low (within 50 points), the battery should be fully charged and the battery charger checked for proper operation. The battery top surface should be clean. Surface contamination can produce leakage currents that present a drain on the charger and the battery. Vent holes in the cell caps should be open. Battery terminal connections should be tight and free of corrosion. If the terminal connections are corroded, they should be cleaned with bicarbonate of soda. Battery terminals and cable ends should be cleaned thoroughly. If stranded cable is used it is advisable to cut off the corroded end. If this is not possible, the strands should be separated and cleaned internally. Any dust accumulation on the battery charger should be blown off or wiped clean. Ventilation openings should be clear of obstruction. Terminal connections should be checked for tightness. All relays, lights or horns for indicating such abnormal conditions as grounds, loss of AC power supply, and high or low voltage should be checked to ensure that they are operating properly. During maintenance outages of the AC supply, there may be times when it is necessary to provide a temporary supply to the charger. While being charged, a battery produces and emits a mixture of hydrogen and oxygen gases which is very explosive. Open flames or sparks must not be permitted in close proximity to the batteries. The room or compartment in which operating batteries are located should be well ventilated. Smoking should be prohibited in these rooms or compartments.

d. Instrument transformers. Instrument transformers are used to step down a current or voltage in order to operate a meter or a relay. Indoor-type instrument transformers are normally dry type, except potential transformers (PTs) which may be enclosed in compound-filled metal cases. The more common transformer constructions have the complete transformer molded into one solid mass with only the terminals exposed.

**** CAUTION****

Never open circuit the secondary winding of a current transformer while energized. To do so may result in component damage or personal injury.

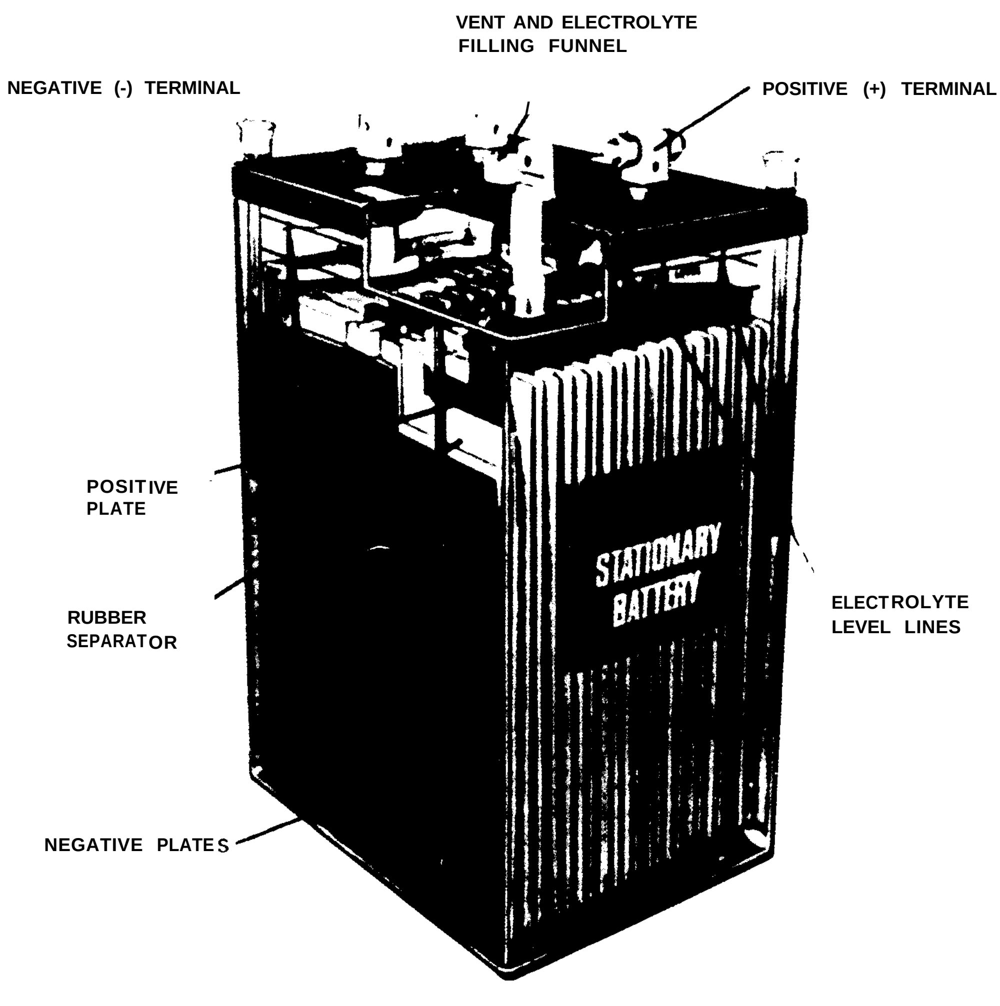


Figure 2-11. Large cell for a stationary battery.

(11) Verify connection of secondary PT leads by applying a low voltage to the leads and checking for voltage contribution at applicable devices.

(12) Check for PT secondary load with secondary voltage and current measurements. Make sure load is less than volt amps (VA) of PT.

f. Metering. Most of the buildings in a typical military installation are unmetered. Meters (both recording and indicating), relays, and associated equipment are usually part of a substation, main distribution switchboard equipment, or special equipment. Industrial shops and other buildings occasionally utilize kilowatt hour demand meters, power factor meters, ammeters, and voltmeters. In an effort to determine whether the maintenance or operation of these meters is adequate demands that the metering instruments be of the specified range, accurately calibrated, and adequately serviced. Instrument accuracy is always expressed in terms of the percentage of error at the full-scale point. Maximum accuracy, consequently, is obtainable by keeping the rating as high on the scale as possible, and requires a properly rated instrument. An instrument with an accuracy of 1 percent, with a scale reading of 100 divided into 100 divisions, is accurate to plus or minus one division. Hence, a reading of 20 has a margin of error of plus or minus one division, which in this instance means that the true value could be between 19 or 21—an actual variation of 10 percent. If the maximum indicating meter reading is less than 50 percent of the meter range, indicating meters should be recalibrated, and ratchets and dials changed. How often an instrument is calibrated depends on its use and the desired accuracy. If calibration standards and equipment are not available, instruments of nearly the same rating may be checked against each other. If wide discrepancies are noted, the suspect instrument should be checked by a competent laboratory or returned to the manufacturer. For many military establishments, the utility company will best perform this work. Take care to prevent entrance of dirt or lint into an instrument because this dirt could hinder the actuation of the instrument pointer. Clean the glass with a damp cloth because a dry cloth may induce a static charge on the glass and affect the instrument reading. Breathing on a charged glass discharges it. Never oil instrument bearings. Indicating demand and power factor meters should be tested and recalibrated every 2 years. Single-phase watt hour meters should be tested at least once every 5 years; self-contained polyphase watt-hour meters every 2 years. Transformer watt-hour meters on the secondary system (600 volts and below) should also be tested every 2 years; transformer watt-hour meters on the primary system every year. Voltmeters and ammeters should be calibrated at 2-year intervals.

g. Alarms. Alarms associated with transformer overtemperature, high or low pressure, circuit breaker trip, accidental ground on an ungrounded system, cooling water flow or overtemperature, or other system conditions should be tested periodically to assure proper operation.

h. Indicators. Circuit breaker “open-close” indicators can be checked during their regular maintenance. Ground indicator lamps for ungrounded electric systems should be checked daily or weekly for proper operation. Other miscellaneous indicators such as flow, overtemperature, excess pressure, etc., should be checked or operated periodically to assure proper operation.

i. Protective relaying. While the application of circuit protection as developed in a short circuit and coordination study is an engineering function, assurance that this designed protection remains in operation is a maintenance responsibility. Applying relay settings and periodically testing them are maintenance functions. Relays should be examined to ensure the following:

(1) All moving parts are free of friction or binding.

(2) All wiring connections are tight.

(3) All contacts are free of pitting or erosion.

(4) solenoid coils or armatures are not overheated.

(5) Glass, covers or cases are not damaged.

j. For relay testing procedures, refer to chapter 14. The protective relay circuitry should also be checked by closing the breaker in the test position and while documenting, closing the contacts of each protective relay to trip the circuit breaker.

2-9. Switchgear trouble-shooting.

Table 2–2 provides detailed information regarding trouble-shooting switchgear failures. Probable causes along with recommended remedies are listed for typical failures.

Table 2-2. Trouble-shooting procedures for switchgear equipment.

CAUSE	REMEDY
1. Meters Inaccurate	
Dirt or dust may be impeding movement; particles may be adhering to the magnets	Clean, test and calibrate meter.
Meter may be damaged - have a cracked jewel, rough bearing, bent disk or shaft, insufficient disk clearance or damaged coils.	Repair or replace damaged parts, test and calibrate meter.
Loose connections.	Tighten test and calibrate meter.
C.T. circuit shorted or shorting strap left	Remove the short.
2. Meters Failing to Register	
Blown potential transformer fuse.	Renew blown fuses. Ascertain reason and correct trouble.
Broken wires or fault in connections.	Repair break, correct fault.
Wedge or block accidentally left at time of test or inspection.	Remove wedge or block, test and calibrate meter.
C.T. circuit shorted or shorting strap left.	Remove the short.
3. Damaged Control, Instrument Transfer Switch or Test Blocks	
Burned or pitted contacts from long use without attention or from unusual conditions.	Dress or clean burned contacts, or replace with new contacts if necessary.

Table 2-2. Trouble-shooting procedures for switchgear equipment - continued.

CAUSE	REMEDY
4. Relays Failing to Trip Breakers	
Improper setting.	Adjust setting to correspond with circuit conditions.
Dirty, corroded or tarnished contacts.	Clean contacts with burnishing tool. Do not use emery or sandpaper.
Contacts improperly adjusted.	Readjust so that contacts close with proper amount of wipe.
Open circuits or short circuits in relay connections.	Check with instruments to ascertain that voltage is applied and that current is passing through relay.
Improper application of target and holding coil.	Target and holding coils should correspond with tripping duty of breaker to assure proper tripping.
Faulty or improperly adjusted timing devices.	If timing device is of bellows or oil-film type, clean and adjust. If of induction-disk type, check for mechanical interference.
5. Noises Due to Vibrating Parts	
Loose bolts or nuts permitting excessive vibration.	Tighten.
Loose laminations in cores of transformers. reactors, etc.	Tighten any loose nuts or core clamps.
6. Connections Overheating	
Increase of current due to additional load that is beyond normal current rating of bars or cables.	Increase the number or size of conductors. Remove excess current from circuit.
Bolts and nuts in the connection joints not tight.	Tighten all bolts and nuts. Too much pressure must be avoided.

Table 2-2. Trouble-shooting procedures for switchgear equipment - continued.

CAUSE	REMEDY
7. Failure in Function of All Instruments and Devices Having Potential Windings	
Loose nuts, binding screws or broken wire at terminals.	Tighten all loose connections or repair broken wire circuits.
Blown fuse in potential transformer circuit.	Renew fuses.
Open circuit in potential transformer primary or secondary.	Repair open circuit and check entire circuits for intactness and good condition.
C.T. circuit shorted or shorting strap left.	Remove the short.
8. Breaker Fails to Trip	
Mechanism binding or sticking due to lack of lubrication.	Lubricate mechanism.
Mechanism out of adjustment.	Adjust all mechanical devices, such as toggles, stops buffers, opening springs, etc., according to instruction book.
Failure of lacking device.	Examine surface of latch. If worn or corroded, it should be replaced. Check latch wipe and adjust according to instruction book.
Damaged trip coil.	Replace damaged coil.
Blown fuse in control circuit (where trip coils are potential type).	Replace blown fuse.
Faulty connections (loose or broken wire) in trip circuit.	Repair faulty wiring. See that all binding screws are tight.